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The Electronic Transfer of Information and Aerospace Knowledge Diffusion

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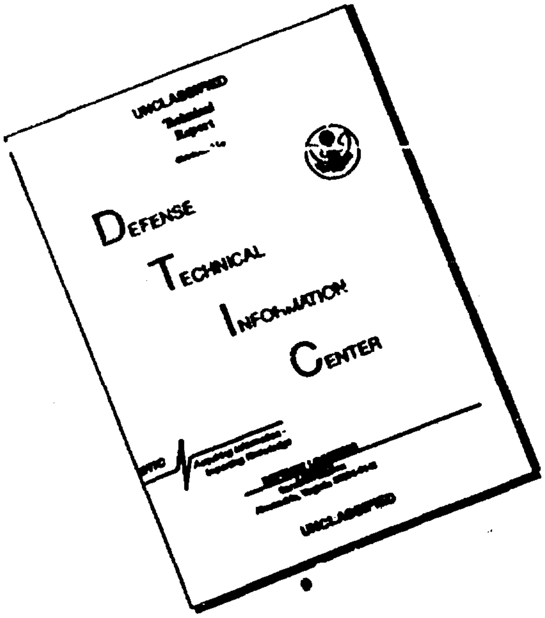

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The Electronic Transfer of Information and Aerospace Knowledge Diffusion

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Increasing reliance on and investment in information technology and electronic networking systems presupposes that computing and information technology will play a major role in the diffusion of aerospace knowledge. Little is known, however, about actual information technology needs, uses, and problems within the aerospace knowledge diffusion process. The authors state that the potential contributions of information technology to increased productivity and competitiveness will be diminished unless empirically derived knowledge regarding the information-seeking behavior of the members of the social system — those who are producing, transferring, and using scientific and technical information — is incorporated into a new technology policy framework. Research into the use of information technology and electronic networks by U. S. aerospace engineers and scientists, collected as part of a research project designed to study aerospace knowledge diffusion, is presented in support of this assertion.

INTRODUCTION

The NASA/DoD Aerospace Knowledge Diffusion Research Project is being conducted by researchers at the NASA Langley Research Center; the Indiana University Center for Survey Research; the University of Illinois Graduate School of Library and Information Science; and Rensselaer Polytechnic Institute. This research is endorsed by several aerospace professional technical societies, including the American Institute for Aeronautics and Astronautics (AIAA), the Society of Automotive Engineers (SAE), and the Royal Aeronautical Society (RAeS). In addition, it has been sanctioned by the Technical Information Panel of the Advisory Group for Aerospace Research and Development (AGARD) and the AIAA Technical Information Committee.

This four-phase project is providing descriptive and analytical data regarding the diffusion of aerospace knowledge at the individual, organizational, national, and international levels. It is examining both the channels used to communicate and the social system of the aerospace knowledge diffusion process. Phase 1 investigates the information-seeking behavior of U. S. aerospace engineers and scientists and places particular emphasis on their use of government-funded aerospace research and development (R&D) and U. S. government technical reports. Phase 2 examines the industry-government interface and places special emphasis on the role of information intermediaries in the aerospace knowledge diffusion process. Phase 3 concerns the academic-government interface and places specific emphasis on the information intermediary-faculty-student relationship. Phase 4 explores the information seeking behavior of non-U.S. aerospace engineers and scientists in selected countries.

As scholarly inquiry, this research has both immediate and long-term goals. In the short term, it provides a practical and pragmatic basis for understanding how the results of research diffuse into the aerospace R&D process. Over the long term, it provides an empirical basis for understanding the aerospace knowledge diffusion process itself and its implications at the individual, organizational, national, and international levels. The results of the project should provide useful information to R&D managers, information managers, and others concerned with improving the quality, access, and utilization of government funded aerospace STI [1].

ENGINEERS' USE OF COMPUTER AND INFORMATION TECHNOLOGY: A REVIEW OF THE LITERATURE

Engineers work in teams to research, develop, design, test, and manufacture a wide range of systems, products, and processes. Engineering is a complex activity that

depends on the coordination of many independent efforts and requires creativity as well as scientific, technical, and managerial problem-solving. Communication technologies would, therefore, appear to offer many opportunities for improving the efficiency and effectiveness of engineering work, which is both information- and communication-intensive.

Engineering Work and New Technologies

The popular and professional literature describes engineers' use of computing and communications applications such as computer-aided design (CAD), computer-integrated manufacturing (CIM), engineering information systems (EIS), and electronic mail and conferencing systems. Most of this literature concentrates on the technical, financial, or management aspects of these new systems, but little attention is focused on problems, issues, and impacts from the users' point of view.

A number of authors discuss the strategic importance of new information and communication technologies to organizational performance and present examples from a variety of settings. Walton presents numerous case studies, including one of an aerospace company, to draw out important concepts, strategies, and techniques for improving the implementation process associated with new information technologies. He stresses the importance of considering both the technical and social aspects of system implementation [2]. Keen presents a variety of case studies to support his argument that telecommunications is an important feature of any organization's strategy to improve its competitive advantage [3]. Morton presents a range of perspectives on the introduction and impact of information and communication technologies in today's global economy [4]. All of these authors argue that new technologies are revolutionizing the way people in organizations work and communicate and that the changes which are occurring must be better understood.

Today engineers use computers to perform calculations; to produce and evaluate drawings, designs, and prototypes (CAD/CAM); to maintain and archive the 'corporate memory', i. e., all the contracts, designs, schedules, assumptions, constraints, procedures, data associated with each particular project; to write and edit documents and prepare presentations; to run project management software; and to control equipment. Gunn provides an early report on the use of computers and electronic networks to 'mechanize' design and manufacturing [5]. A collection of papers on the application of computers to engineering design, manufacturing, and management is offered by Lastra, Encarnacao, and Requicha [6]. Ettlie and Stoll present a collection of essays and case studies on managing the design to manufacturing process [7]. This work is especially intriguing because it draws attention to the philosophical and cultural changes that must accompany the implementation of new computing and communications technologies if the desired effects are to be brought about. Rockart and Short describe the need of organizations to manage interdependence. They give a number of examples of engineering firms using electronic networks and computerized tools and databases to integrate the stages of product development, distribution, and service; to support teamwork; and to facilitate coordination and control [8].

The policies, principles, and techniques of 'concurrent engineering', derived from the perceived need to improve industrial productivity and competitiveness, aim to improve engineering quality, reduce costs, increase the speed of product development, and improve customer satisfaction. Concurrent engineering calls for integrating engineering functions so that they may be performed in parallel rather than in series. It strives to improve communication in order to coordinate the work and integrate the information contributed by all of the many people involved in the development, production, and marketing of a particular technology.

Many engineering organizations are exploring the ability of computers and electronic networks to facilitate concurrent engineering and improve the performance of engineers and the technical quality of their work. A report by Lewis et al. provides an in-depth treatment of the methodology and tools for developing networked systems for concurrent engineering at General Electric's R&D headquarters [9]. Kaplan notes that 'today, teamwork and concurrent engineering are the important organizational issues, so workstations must be tied together into networks that optimize the use of shared resources' [10, p. 32].

Computer Use in Engineering

Computer networks are playing an increasingly important role in engineering work because they link design and analysis tools with other important resources to create integrated engineering information systems (EIS) that can be used by engineers from their own desktops. Dirr and Stockdale describe 3M's transition from the use of CAD systems to a distributed computing strategy in which 'all authorized users would have access to information anywhere in the network, and CAD and project management would be joined in a single integrated system' [11, p. 50]. Heiler and Rosenthal define an EIS as the combination of 'software tools, data base managers, data bases and hardware to provide integrated environments for engineering design and management' [12, p. 431]. They also describe the rationale for such systems [12, p. 431]:

> 'Engineering environments can be extremely complex. They must support long, complex, and interdependent tasks that produce and manipulate highly specialized data. Often multiple representations of the same information are required to support different tasks. Moreover, more than one engineer may work concurrently on different aspects of the same design, which may introduce inconsistencies into the data'.

The use of computers and networks to automate the manufacturing process is becoming more widespread. Boll describes the role of the manufacturing automation protocol (MAP) in accomplishing the integration of the manufacturing process: 'machining, assembly, warehousing, quality assurance, packaging and dispatch' [13]. Schatz describes the increase in computer-integrated manufacturing (CIM) investments worldwide, noting that they are expected to double between 1988 and 1992, reaching about $91 billion [14].

Electronic data interchange (EDI) is used to exchange orders and invoices with vendors and suppliers, and contracts with clients and customers [15, 16]. Thus, networks are also used in engineering environments to facilitate formal business communication outside the firm. Networks are used in some firms for information retrieval (IR) in connection with both in-house and commercial databases. Information retrieval systems have received mixed reviews from engineers. Christiansen discusses the results of an informal IEEE survey on how engineers obtain the information they need to do their jobs. He reports that engineers have difficulty performing online searches and often obtain inadequate results. He also interprets the tendency of engineers to 'scan and save' large amounts of material as a response to their dislike of retrieval systems [17, p. 21]. Breton presents a more compelling argument for the underutilization of information retrieval systems. He concludes that the informal and visual material that is important to engineers is not included in most IR systems and, further, that current indexing techniques fail to retrieve information according to those dimensions, such as 'desired function', that are useful to engineers [18, 19]. Gould and Pearce describe the results of an assessment, based largely on interviews, intended to relate information needs in engineering to current systems for storing, organizing, and disseminating that information [20]. Mailloux reviews current literature on EIS. She provides an overview of a variety of engineering systems and devotes considerable attention to a discussion of how EIS support engineering work and communication behavior [21].

Finally, the literature suggests that engineers also use electronic networks for a variety of interpersonal communication purposes. Borchardt includes electronic mail among his suggestions for improving in-house technical communication in order to facilitate the sharing of ideas, provide a more stimulating work environment, and prevent the duplication of efforts [22, p. 135]. Beckert notes that engineers can use electronic mail to send text, data, and graphics to their colleagues and to automate the notification status change process between engineering, manufacturing, and external entities. She notes that electronic communication eliminates telephone tag and problems associated with time-zone differences and also saves time in scheduling meetings and responding to technical questions [23, p. 68]. Mishkoff describes computer conferencing as the answer to the problems corporations face when they employ geographically-dispersed work groups. He reports that Hewlett-Packard employs thousands of engineers in over 70 divisions, one-third of which are located outside the United States, and describes how computer conferencing is used in place of more expensive mechanisms to allow groups of engineers to share their knowledge efficiently and coordinate their work [24, p. 29].

The power of computer conferencing systems to form the base of 'electronic expert networks' in organizations is described by Stevens, although he does not focus exclusively on engineers. His discussion applies the assertions about the importance of informal communication in organizations to the electronic environment. He argues that electronic networks are an important source of expertise for employees because 'the best answers frequently come from surprising sources. An unknown peer with relevant experience can sometimes provide better help than a more famous expert, who may be less accessible or less articulate' [25, p. 360]. Stevens also notes that 'while expert networks can be used by traditional organizations to strengthen their effort to produce and provide products and services, expert networks also seem to represent almost a new form of organization' [25, p. 369].

Many organizations hope that by facilitating communication and improving the coordination, electronic networks will decrease both the costs and the time needed by firms to bring products to market. Due to proprietary and security concerns, a number of engineering organizations have implemented private, high-speed networks that are used only by their own employees. The need for high-bandwidth, completely reliable electronic transfer of critical data also makes the use of most public commercial networks infeasible for some industries and applications. Werner and Bremer note that even companies involved in industry-academia-government R&D cooperatives prohibit electronic links to external consortium members for fear of security leaks [26, p. 46].

The National Research Council's Panel on Engineering Employment Characteristics conducted an informal survey of engineering employers in which they obtained employers' views on the impact of new tools on engineering productivity [27]. Survey results indicated that about one-third of employers had widely available computer-aided drafting or design systems in place, few had computer-aided manufacturing systems, and about 50 percent had engineering information systems [27, p. 68]. Fewer than one half of the respondents had formally evaluated their systems, although they estimated productivity gains of about 100 percent for drafting systems, 50 percent for design systems, and 35 percent for information systems. The Panel concluded that 'these new computer-aided tools permit increasingly sophisticated products to be designed in less time with substantially greater accuracy and with greater cost-effectiveness' [27, p. 27] although they also noted that 'their net effect on engineering and on industry as a whole cannot be forecast with confidence' [27, p. 26].

The aerospace industry possesses a number of characteristics that make it a natural environment for the use of information technology. It is a high technology industry, already highly computerized. It involves significant R&D, which is a communication-intensive activity. Further, its end products are highly complex, calling for a great deal of work task coordination and the integration of information created by diverse people. In describing the business and technology strategy in place at British Aerospace, Hall emphasized the need for increased computing and communications capabilities in aerospace firms aiming to design, develop, make and market complex systems while maintaining a technical competitive edge and reducing costs [28, p. 16-2]. He noted that a number of typical information technology opportunities were particularly relevant to the aerospace industry, such as 'improved productivity, better competitive edge, reduced time scales, closer collaboration, more streamlined management, better commonality of standards across sites, more operational flexibility, [and] constructive change of work-force skill levels' [28, p. 16-2].

Rachowitz et al. describe efforts at Grumman Aerospace to realize a fully distributed computing environ-

ment. Grumman's goal is to implement a system of networked workstations in order to 'cost-effectively optimize the computing tools available to the engineers, while promoting the systematic implementation of concurrent engineering among project teams' [29, p. 38]. The network includes PCs and software to be used for communication. Grumman assumes that their computer/information integrated environment (CIE) will result in 'product optimization, quality products manufactured with fewer errors in shorter time and at a lower cost' [29, p. 66].

Black presents a brief overview of the uses and advantages of computer conferencing systems, noting that computer conferencing is a 'very powerful tool for the transfer of information in all areas of research and development and a natural for the AGARD community' [30, p. 13-4]. Molholm describes the application of the Department of Defense Computer-aided Acquisition and Logistics Support (CALS) initiative to the aerospace community. CALS mandates the use of specific standards for the electronic creation and transmission of technical information associated with weapons systems development. Eventually all Department of Defense contractors and subcontractors will be required to create and distribute in digital form all the drawings, specifications, technical data, documents, and support information required over the entire life cycle of a military project. The CALS system may provide a significant impetus to networking for aerospace firms [31].

Shuchman conducted a broad-based investigation of information transfer in engineering [32]. The respondents represented 14 industries in the following major engineering disciplines: aeronautical, chemical and environmental, civil, electrical, industrial, and mechanical. As part of this study, Shuchman examined the use of computer and information technology by engineers to 'identify the attitudes [of engineers] toward and use patterns of computer and information technology in an effort to forecast the potential value of new information technologies' [32, p. 36]. Overall the survey results indicated that computer and information technology has high potential usefulness but relatively low use among engineers. In analyzing this finding, it is important to keep in mind that the state of the art in computer and information technology has changed dramatically since Shuchman's study was released.

In Shuchman's study, respondents were asked to indicate the use, non-use, and potential use of 21 computer and information technologies categorized into four groups. Overall, aeronautical engineers made greater use of computer and information technologies than did the other respondents. Aeronautical engineers also reported the highest use of 'information transmission technologies' (fax, telex, teleconferencing, and video conferencing). They also had the highest use rate for what Shuchman identified as 'recorded/pre-recorded information technologies'. Of the emerging technologies (e. g., digital imaging); aeronautical engineers reported the highest rate of current use and predicted use.

A pilot study conducted as part of Phase 1 of the NASA/DoD Aerospace Knowledge Diffusion Research Project investigated the technical communications habits and practices of U. S. aerospace engineers and scientists [33]. One of the objectives of this study was to determine the use and importance of computer and information technology to them. Approximately 91 percent of the respondents reported using computed and information technology to communicate STI. Approximately 95 percent of those respondents who reported using this technology indicated that it had increased their ability to communicate. The lowest rates of use for any technology were those reported for the mature technologies (e. g., micrographics). The rate of use for maturing technologies (e. g., electronic databases) was relatively high, approximately 60 percent. Overall, 50-60 percent of the respondents predicted that they would use the nascent or emerging technologies (e. g., electronic networks).

Summary

The literature reveals that a number of engineering organizations are using electronic networks for a variety of communication activities, distributed computing, and shared access to information resources. Networks are being implemented to serve organizational goals and business strategies, i. e., to achieve impacts in terms of better and faster product development and cost savings. Such motivations for network investments suggest factors that may encourage network use in particular engineering organizations and obviate the need for them in others. The literature also hints at a number of factors that may hinder network use, such as security and proprietary concerns, the failure of indexing techniques to retrieve stored information in a way useful to engineers, and the substantial financial outlays required to implement networked systems.

PRESENTATION OF THE DATA

In this presentation, we report data from three surveys conducted as part of the Project. Two mail surveys were based on samples of the members of the American Institute for Aeronautics and Astronautics (AIAA). The third survey was based on a list of readers of *Aerospace Engineering* provided to us by the Society of Automotive Engineers (SAE). From the AIAA list, two random samples were drawn to select 3,298 (sample one) and 1975 (sample two) persons from their 1989 membership list. Overall 2,016 aerospace engineers and scientists responded to the first survey and 975 responded to the second survey. The adjusted response rate (correcting for sample problems) for both of the surveys was about 70 percent. The surveys were conducted during summer and fall of 1989. The SAE survey was conducted by telephone during August 1991. A sample of 670 persons yielded interviews with 430 respondents. Again, after correcting for sample problems, the response rate was approximately 70 percent.

Demographics

Data are presented from both AIAA surveys and the SAE survey because they indicate some differences among the use of computer and information technology. First the AIAA surveys asked different questions about the use of information technology. Second, the surveys were conducted approximately two years apart, so we

can measure some recent changes in technology use among aerospace engineers and scientists.

There are some differences between the two organizations (see table 1). The AIAA is a professional research society and the characteristics of its members reflect a research orientation. Over 31 percent of the respondents hold a doctorate and an additional 39 percent have earned master's degrees. Most of the sample are managers, designers, developers, or researchers. Of the 28 percent who reported their principal job activity as design/development, we expect them to be especially involved in information production, transfer, and use.

Table 1

Characteristics of the AIAA and SAE samples (N=1839; N=430)

Characteristics	AIAA (%)	SAE (%)
Education		
No Degree	1	9
Bachelor's Degree	27	51
Master's Degree	39	35
Doctorate	31	4
Other	2	1
Organization type		
Academic	13	1
Government	23	12
Industry	53	86
Other	11	1
Occupation		
Engineer	68	66
Scientist	8	1
Manager/Other	24	33
Duties		
Research	17	14
Management	39	*
Design/Development	28	77
Teaching	10	*
Other	6	9
Years employed in aerospace		
Less than 10	27	24
10—19	22	21
20—29	26	20
30—39	22	27
Over 40	3	8

*Not asked.

The distribution of the characteristics of the readers of *Aerospace Engineering* shows a number of differences between the two groups surveyed, particularly in education, organizational affiliation, and professional duties. Seventy-seven percent of the SAE indicated their duties involved design/development compared to 28 percent for the AIAA. Relatively few of the SAE sample have earned doctorates (4 percent vs 31 percent) and a much higher percentage have earned bachelor's degrees only (51 percent vs 27 percent). About 86 percent of the SAE were employed in industry compared to 53 percent of the AIAA sample.

Use of Computer and Information Technology

The data in Table 2 are from the first AIAA survey [34]. Fifteen computer and information technologies were placed in three groups: mature, developed, and emerging. Mature technologies include videotape, fax, telex, micrographics and microfilms. Developed technologies include teleconferencing, video conferencing, and electronic databases. Emerging technologies include electronic networks, bulletin boards, e-mail, laser disks, video disks, and CD-ROM products. Their use by AIAA members was analyzed for differences. Those who reported using at least one of the technologies in their work are considered to be users.

Table 2

Use of computer and information technologies by selected characteristics (AIAA survey; N=1839)

Characteristics	Percentage using		
	Mature technology	Developed technology	Emerging technology
Education			
Bachelor's Degree or less	94	79	65
Graduate Degree	94	73	64
Education/career preparation			
Engineer	94	74	66
Scientist	92	74	67
Years in aerospace			
Under 15	94	72	69
15 or more	94	75	64
Organization			
Academic	91	68	65
Government	95	80	75
Industry	96	76	63
Duties			
Managers	95	80	69
Others	93	70	65

Aerospace engineers and scientists in the AIAA sample tend to use many forms of computer and information technology. Almost all used the mature technologies. Smaller percentages use the developed and the emerging technologies. While the emerging technologies were least often used, they were used by at least two-thirds of the sample. Overall, there were very few characteristics which distinguished users from non-users.

Respondents to the second AIAA survey were asked a series of questions regarding their use of STI in specified electronic formats (see table 3). In particular, they were asked how likely they would be to use data tables/mathematical presentations and computer program listings in electronic form. They were also asked how likely they would be to use online systems and CD-ROM products as replacements for technical reports that currently are produced in paper and fiche formats. Those who said they were unlikely to use these products in electronic forms were asked why.

A majority of aerospace engineers and scientists reported that they would be likely to use data tables/mathematical presentations and computer program listing in electronic form. Among those who selected 'not likely to use', no reason predominated as an explanation of non-use. About one-third said they would have some computer access or compatibility problems that make it unlikely they would use these forms. More than 50 percent of the sample would consider using online versions of technical reports, but a significant proportion expressed a preference for printed formats. It appears that the cost (embedded in 'other') and computer availability/access would prevent many aerospace engineers

Table 3

Attitudes toward the use of STI in specified electronic formats (AIAA survey; N=975)

Format	Likely to use (%)	Not likely to use (%)	Reason(s) not likely to use (%)
Data tables/mathematical presentations	57	43	
Computer availability/access			13
Hardware/software incompatibility			14
Prefer printed form			42
Other			31
Computer program listings	55	45	
Computer availability/access			16
Hardware/software incompatibility			19
Prefer printed form			28
Other			37
Online technical reports	56	44	
Computer availability/access			17
Hardware/software incompability			12
Prefer printed form			51
Other			20
Technical reports on CD-ROM	39	61	
Computer availability/access			23
Hardware/software incompatibility			27
Prefer printed form			32
Other			18

and scientists from using technical reports if they were available on CD-ROM.

The data in Table 3 are consistent with the findings presented in Table 2. Most of the sample are using computer and information technologies and would be likely to use them even more if the information they were seeking were available electronically. There is some indication that the access to CD-ROM products in 1989 made some of the respondents feel they were not likely to receive technical papers if they were made available on CD-ROM. If this question were asked again in 1995, the percentages favoring this format would likely be higher.

Use of Electronic Networks

Changes in the accessibility of computer and information technology and electronic networks have occurred rapidly over the past few years. These changes would be especially quick in the technologically sophisticated aerospace industry. One portion of the SAE survey focused specifically on the use of electronic networks. One of the objectives of the SAE survey was to collect descriptive data on network use by aerospace engineers and scientists. The questions covered the following topics:

— Network availability and frequency of use
— Network use to access remote sites
— Network use for particular functions
— Types of electronic communication partners
— Nature of electronic communication.

In most of the following tables, the results are presented according to respondents' self-reported categories of work identified as 'basic research', 'applied research', 'process/product development', 'manufacturing', or 'other'. (Because of the grossly uneven number of respondents in each category, the results derived from the category breakdown must be taken as merely suggestive.) Although all respondents may be assumed to be involved in engineering work, broadly defined, the analysis by the five work categories is useful in that it does suggest the nature of the daily activities probably performed by people in each category. The overwhelming majority of respondents defined themselves as 'engineers' and were employed in industry. (Other demographic characteristics appear in Table 1.)

The percentage of SAE survey respondents in each work category who reported having access to electronic networks appears in Table 4. In general, respondents

Table 4

Network access by work categories (n=297)

Work Categories	n	%
Basic research	4	75
Applied research	40	83
Process/product development	172	87
Manufacturing	32	69
Other	44	82

paint a picture of widespread use of electronic networks within the U. S. aerospace industry, with relatively slight variation by work categories. A majority of the respondents (83% overall) reported having workplace access to electronic networks.

One portion of the SAE survey conducted last August focused specifically on the use of electronic networks for remote site access (see Table 5). The percentages in

Table 5

Use of networks by work categories to access remote sites (n=229)

Work Categories	n	%
Basic research	3	100
Applied research	29	72
Process/product development	144	71
Manufacturing	19	79
Other	34	62

Table 5 are based on SAE respondents who use electronic networks. (Eighty percent of the respondents who have access to electronic networks report using them.) A majority of the respondents (71% overall) reported using electronic networks to access remote sites.

Reported frequencies of network use by work categories appear in Table 6. Overall, network use in basic research exceeds network use in the remaining work

Table 6

Frequency of network use by work categories (n=247)

Work categories	Frequency (%) per day	per week	per month	seldom	never	n
Basic research	33	67	0	0	0	3
Applied research	47	6	28	13	6	32
Process/product development	42	19	12	20	6	154
Manufacturing	54	5	23	5	14	22
Other	33	14	31	17	6	36

categories. Daily and weekly use in basic research also exceeds use in the remaining categories. Respondents in manufacturing reported the highest percentage of 'non-use'. Respondents in process/product development reported the highest percentage of use characterized as 'seldom'.

Respondents were asked to indicate their use of specific network functions (see Table 7). Overall use of

Table 7

Network function use by work categories (n=230)

Work categories	Function (%) EM	BB	FT	RL	RC	IR	n
Basic research	100	100	100	67	33	100	3
Applied research	86	45	77	69	23	73	30
Process/product development	77	49	79	56	15	74	230
Manufacturing	74	52	84	52	16	94	19
Other	74	47	76	47	18	76	34

EM — e-mail, BB — bulletin board, FT — file transfer, RL — remote login, RC — remote control, IR — information retrieval

network functions varied from a high of 79% for file transfer, 78% for e-mail, and 77% for information retrieval to a low of 16% for remote control. Respondents in basic research made the greatest use of e-mail, bulletin boards, file transfer, and information retrieval. The least used network function by respondents in all work categories is remote control.

Other survey questions further explored the nature of network communication (see Table 8). About three

Table 8

Electronic communication by partners (n=240)

Percentage of respondents communicating electronically with —		
Work group members	Others in organization	People outside organization
76	76	50

fourths of the respondents reported that they communicated electronically with people in their work group and others in their organization, while fully half responded that they used networks to communicate with people outside of their own organization.

Finally, respondents were asked to recall and report the purpose of a recent electronic exchange (see Table 9). The majority of reported exchanges were related to

Table 9

Electronic communication by function (n=240)

Number of respondents communicating electronically by function —			
Technology	Administrative	General information exchange	Social
155	103	38	20

what might be termed 'technical' communication, including such things as sending data, asking technical questions, receiving specifications, and solving technical problems. Somewhat fewer examples of 'administrative' exchanges were noted and substantially fewer respondents reported a recent exchange as being either a 'general information' or 'social' exchange.

KNOWLEDGE DIFFUSION, THE AEROSPACE INDUSTRY, AND INFORMATION TECHNOLOGY

A global economy and expanding international marketplace will result in a more rapid diffusion of technology, increasing pressure on the aerospace industry to push forward with new technological developments and to take steps that maximize the inclusion of those developments into the R&D process. However, it is important to note that innovation-adoption decisions are seldom made on the basis of 'advances in systemic knowledge of the useful arts', otherwise known as STI. They are, in large part, investment decisions that are influenced to a great extent by monetary and fiscal policy, tax laws, workplace rules, and industry regulations. A well-articulated set of innovation-adoption technology policy goals, together with a coherent integrated program directed at attaining such goals, is needed as a means of enhancing technological innovation and improving economic competitiveness within the aerospace industry.

Experts agree that a strong technology or knowledge base is needed to enhance technological innovation and improve economic competitiveness. Studies show a positive relationship between a strong technology or knowledge base and successful innovation, technical performance, and increased productivity. However, a growing number of individuals are questioning the relevance of 'supply-side' technology policy with its 'trickle-down' benefits as inadequate for aerospace to remain competitive in the global market place of the 1990s and beyond. Existing 'supply-side' technology policy is product, not process oriented; it emphasizes knowledge production but not its transfer and utilization; and it relies on 'applications and demonstration' projects for commercializing technology prototypes.

These same experts recommend that 'supply-side' technology policy, with its STI component derived from 'appropriability and dissemination' information models, be replaced by 'diffusion-oriented' technology policy. (See Ballard, et al. [35]; Williams and Gibson [36] for

a discussion of the appropriability and dissemination models). Diffusion-oriented technology policy has its basis in an applied economic framework that views knowledge production, transfer, and utilization as equally important components of the R&D process. Diffusion-oriented technology policy is thought to increase the power to absorb and employ new technologies productively. (See Branscomb [37] for a discussion of diffusion-oriented technology policy). Diffusion-oriented aerospace technology policies assume that a positive relationship exists between attempts to stimulate aerospace technological innovation and government funded STI and that an STI transfer infrastructure funded and coordinated as a partnership between industry, academia, and the government is essential. (See Pinelli, Barclay, Bishop, and Kennedy [38] on this point.)

Diffusion-oriented technology policies would, of necessity, include a coordinated STI component. These policies would view the structure, organization, and management of STI as a strategic resource. These policies would also commit the partnership to building and maintaining a technology infrastructure that includes an STI transfer component based on a knowledge diffusion model. This model would have an 'activist' component that emphasizes both domestic and imported STI; it would be responsive in a 'user' context; and it would make considerable use of information technology. It is worth noting that the 'half-life' of information is getting shorter, and the comparative advantages of organizations consist more in knowing how and when to use information rather than in simply having it.

The need for more frequent and effective use of information technology characterizes the strategic vision of today's competitive aerospace marketplace. Aerospace STI policy should also reflect this same strategic vision for the following reasons. Studies estimate that approximately 80 percent of the duties performed by engineers involve the production, transfer, and use of STI. These same studies indicate that the ability of aerospace engineers and scientists to identify, acquire, and utilize STI is of paramount importance to the efficiency of the R&D process. Testimony to the central role of STI and the R&D process is found in numerous studies that have reported a strong relationship between the communication of STI and technical performance at both the individual and group levels. These results support the conclusion that STI is central to the success of aerospace R&D, the management of aerospace R&D activities, and the aerospace R&D process itself.

CONCLUDING REMARKS

The use of information technology and electronic networking systems in aerospace is widespread and growing rapidly. This technology is making the same STI available at the same time to all competitors. Furthermore, a considerable body of literature suggests that information technologies and electronic networking systems are having a revolutionary impact on the way aerospace engineers and scientists work and communicate. The expanding international marketplace is bringing about significant changes in the philosophy and culture of aerospace organizations. The emergence of concurrent engineering calls for integrated engineering functions and improved communication among individuals and teams that will lead to faster and better product development and cost savings. Many aerospace firms are looking to information technology and electronic networking systems to provide the communication functions that are necessary in concurrent engineering.

Little empirical evidence has been gathered, however, about the information-seeking behavior of aerospace engineers and scientists and the role that information technology and electronic networking systems play in the information-seeking and use process. Although such information would be useful for designing aerospace information systems and developing aerospace information policy, we know little about the diffusion of knowledge in the aerospace industry, both in terms of the channels used to communicate and the social system of the aerospace knowledge diffusion process. The NASA/DoD Aerospace Knowledge Diffusion Research Project has taken the first steps toward providing this information and establishing a practical and pragmatic basis for understanding the aerospace knowledge diffusion process.

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